CHAPTER 8

STRUCTURAL DESIGN

8-1. Structural types.

a. Open piers and wharves. These piers and wharves have open water flowing underneath them and consist of platform structures supported on various types of piles. Open-type construction falls into two classifications:

(1) Relieving platform in which fill is superimposed, topped off by the finished deck.

(2) High-level superstructure in which the deck system is supported directly on the piles. The principal types of open pier and wharf construction are shown in figures 8-1 through 8-10. These types should be used where piers extend out board of legal bulkhead lines. Open construction is also used where tidal and stream prism restrictions should be minimized; where flows in which piers are built carry heavy silt loads; and where bottoms are soft. For pier widths up to 125 feet, open structures are usually more economical. Open pile structures are not advisable where heavy accumulations of sheet or drift ice occur. Open-type piers are suitable in any water depth.

b. Solid piers and wharves. The deck of a solid pier or wharf is supported in full, whereas the perimeter structure is essentially a continuous bulkhead or quay wall. The principal types of solid piers and wharves are shown in figures 8-11 through 8-15. Solid piers generally require less maintenance than open types. For pier widths greater than 125 feet, and where good foundation material exists at or above dredge levels, solid or combination piers are usually more economical.

c. Combination piers. These piers combine open and solid types with a filled center and open perimeter.

8-2. Deck structure design.

a. Concentrated load distribution to decks.

(1) *Truck loads*. Concentrated wheel loads (including impact) will be distributed to deck slab, stringers, and pile caps in conformity with distribution of wheel loads to deck slabs, stringers, and floor beams of highway bridges specified in AASHTO specification.

(2) *Railroad loads*. Concentrated wheel loads (including impact) will be distributed to supporting slabs, stringers, and pile caps of steel frame structures in accordance with AREA specifications. For concrete structures, the live loads (including impact) should be distributed over widths of tracks.

(3) *Wheel loads through fill*. These loads should be distributed in accordance with AASHTO specifications for truck wheels and the AREA specifications for railroad locomotive wheels.

b. Timber deck requirements (figure 8-16).

(1) *Caps.* Two types of caps are in general use: (a) single piece timbers across the tops of the piles (b) a pair of clamps dapped into the tops of piles at the sides. The single-piece cap is preferred. Caps will be strapped to piles.

(2) *Anchorages for deck fittings*. Bollards, bitts, and cleats should be anchored to decks and piling by using spiral-drive drift bolts and metal straps.

(3) *Deck planks and treads*. In addition to planks, timber decks designed for truck loadings should be provided with treads. Treads should be 3 inches minimum. Do not consider treads as load-carrying members.

(4) *Bridging.* Place solid bridging between stringers over all pile caps. One intermediate line of solid bridging will be placed at the midpoints of all spans between 21 and 40 feet, and two lines at the third points of spans 41 to 60 feet.

(5) *Stringers.* These stringers will bear on full widths of caps and should lap adjacent stringers. Lapped ends of untreated stringers should be separated 0.5 inch and blocked.

c. Concrete deck requirements. General design requirements will conform to the current American Concrete Institute (ACI), AASHTO, and AREA specifications. Special reinforcement may be provided to distribute loads from deck fittings.

d. Composite deck requirements. For timber-concrete decks, concrete slab and timber caps shall conform to timber and concrete deck requirements specified above. For timber-steel and steel-concrete decks, concrete and timber slabs and caps should conform to timber and concrete deck requirements.

e. Solid and combination pier decks. Requirements for these types of decks are indicated below.

(1) *Interior columns for pier shed*. These columns should be carried on isolated pile caps or piers supported at or below the dredge line. Some loss of fill is inevitable. Therefore, this loading requirement is necessary to prevent undermining shallow supports.

(2) *Pavement.* Where cargos are stacked on pavements exposed to the sun or where iron-rimmed wood or similar wheeled vehicles run on pavement, use concrete slabs. Elsewhere, flexible pavements are preferable. Where concrete pavements are used, provide expansion joints where the pavement passes over the inboard edge of cells or relieving platform.

(3) *Railroad and crane tracks*. These tracks may be supported on ties and ballast placed directly on select fills. Where tracks run over relieving platforms, loads should be distributed to the platforms as specified for distribution of wheel loads through fill.

(4) *Deck fittings.* Connect bollards, bitts, and cleats to separate foundations embedded in the fills or tie to bulkhead, platforms, or cell structures.

(5) *Lost fill*. Where feasible, provide access for replacement of fill losses in solid or combination structures (some losses through interlocks and other openings are inevitable).

f. Other requirements. Provide side curbs, 12 to 15 inches high, for decks. For drainage, decks should be crowned or pitched 0.0625 inch per foot, and deck drains or scuppers provided. Scuppers should be a minimum of 2 inches high. Provide minimum 3-inch downpipes for drains and weep holes in all rail slots. For deck finish, provide float finish (in shed areas, a floor hardener is desirable).

8-3. Substructure design.

a. Load combinations. Pier substructures should be designed for dead loads, plus vertical live loads, plus lateral load of mooring or berthing ship, with normal allowable stresses; and for dead load, plus half a vertical live load, plus seismic load (based on dead load plus half a live load), with a one-third increase in normal allowable stresses of allowable pile capacity.

b. Piling requirements. The design of pile foundations depends upon three basic considerations: first, a consideration of the soil properties and capacities usually determined from soil boring tests; second, the study of pile types and driving equipment using a dynamic pile-driving formula; and third, the study of pile carrying capacities using a static formula. Testpile and test-load results are usually combined with these studies to achieve best results in pile foundation design.

(1) The following factors should be considered when selecting pile material:

(a) required length of life.
(b) character of structure.
(c) availability of materials.
(d) type of loading.
(e) factors causing deterioration.
(f) amount and ease of maintenance.
(g) estimated costs of types of piles, taking into consideration initial cost, life expectancy, and cost of maintenance.
(h) available funds.

(2) The principal factors which cause piles to deteriorate are:

(a) corrosion.
(b) decay.
(c) insect attack.
(d) marine-borer attack.
(e) mechanical wear.
(f) fire.
(g) chemical reaction (concrete).

In the case of foundation piles buried in the ground, only the first three factors need to be considered. In the case of piles supporting water-front structures, all of these environmental factors must be considered.

c. Fill material. Coarse-grained materials, such as sand, gravel, and rock, are suitable for fill. Fine-grained materials such as silt, or cohesive materials such as clay, are generally not satisfactory because of shrinkage, expansion, or settlement and will result in high maintenance costs and an unsatisfactory base for floors. Coarse-grained, cohesionless materials will be compacted to at least 95 percent of modified AASHTO maximum density, and fine-grained cohesive materials to at least 90 percent of modified AASHTO maximum density.

d. Bent spacing. Pier supporting transit sheds should have substructure pile bents spaced at an integer fraction of the shed column spacing. Provide a pile cap located under each column. Bent spacing from 10 to 24 feet is common for piers without sheds.

e. Other requirements. As to resistance to longitudinal loads, piers wider than 60 feet, and with expansion joints more than 400 feet apart, do not require batter piles for longitudinal resistance, unless designed for multiple berthings. Piers less than 60 feet wide should be investigated for longitudinal loads due to wind, ice, current, traction, and braking. Batter piles or longitudinal braces required for longitudinal resistance may be grouped near the center of pier lengths. As to scouring, piling (and/or sheet piling) should be adequately embedded to provide for anticipated scourings.

8-4. Miscellaneous considerations.

a. Expansion joints. Typical expansion joint detail is shown in figure 8-17. Slip joints for all rails, pipes, and ducts should be provided.

(1) *Size.* Expansion joints should provide for temperature changes of 600 F in moderate climates and 700 F in cold climates.

(2) *Shear connectors*. Provide shear connectors to prevent relative transverse movements of pier sec

tions. Shear connectors may consist of wide flange sections cased in slip sleeves.

(3) *Spacing.* Make the spacing as large as possible but do not exceed 600 feet. Piling should be checked for bending due to longitudinal expansion caused by temperature changes.

b. Future expansion. Where consideration is being given to constructing a pier in stages, provide the following details in the structure to facilitate future expansions:

(1) *Concrete structures*. Leave dowel bars projecting from first-stage construction. Dowel bars should be enameled and wrapped for anchor rods. Leave keys in abutting faces, and let pile caps project beyond pier edges. Use timber instead of concrete curbs on the side or end for future enlargement.

(2) Timber structures. No special provisions are required.

c. Wind screens. Where sheltering in the form of buildings or similar features is lacking at a given site, and where exposure is severe, wind screens may be used to reduce difficulties of berthing.

d. Relation to upland facilities. Switch yards and turnarounds may be provided in close proximity to the inshore ends of piers.

e. Navigation aids. Detailed information is provided in U.S. Coast Guard Booklet CG-208, Aids to Navigation Regulations (see app A). A foghorn is needed and fog lights should be provided on pier ends.

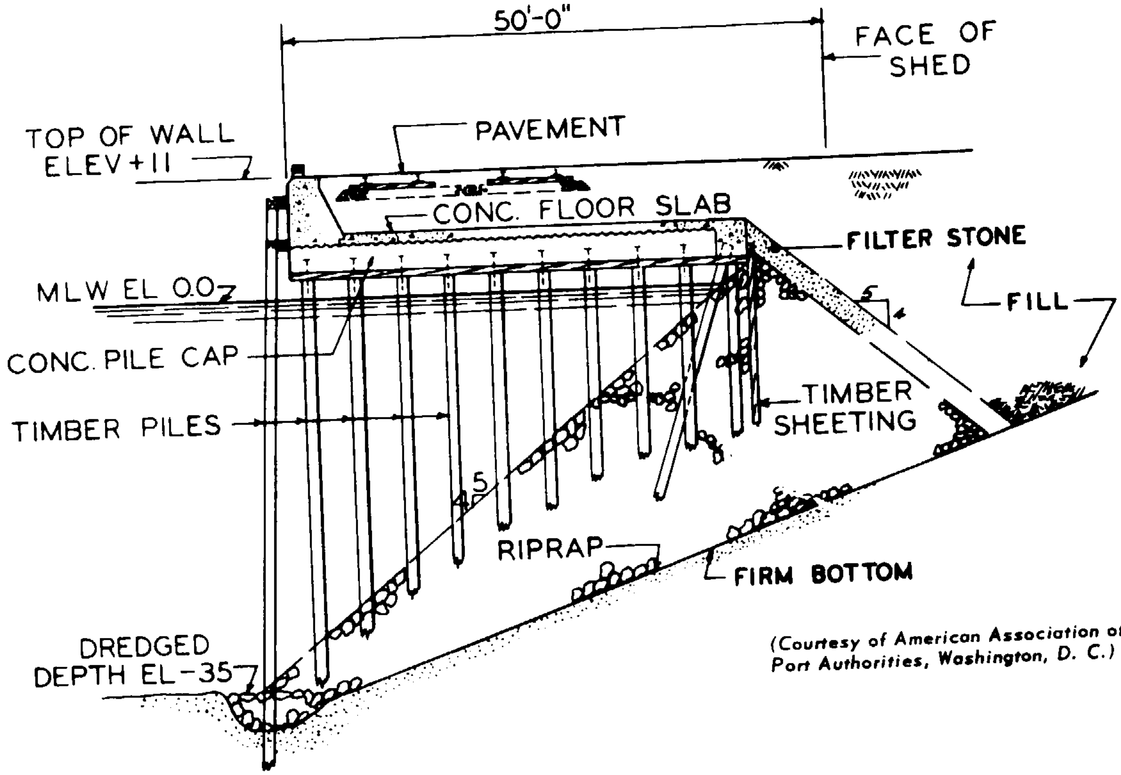


Figure 8-1. Open Type Wharf Construction with Concrete Relieving Platform on Timber Piles.

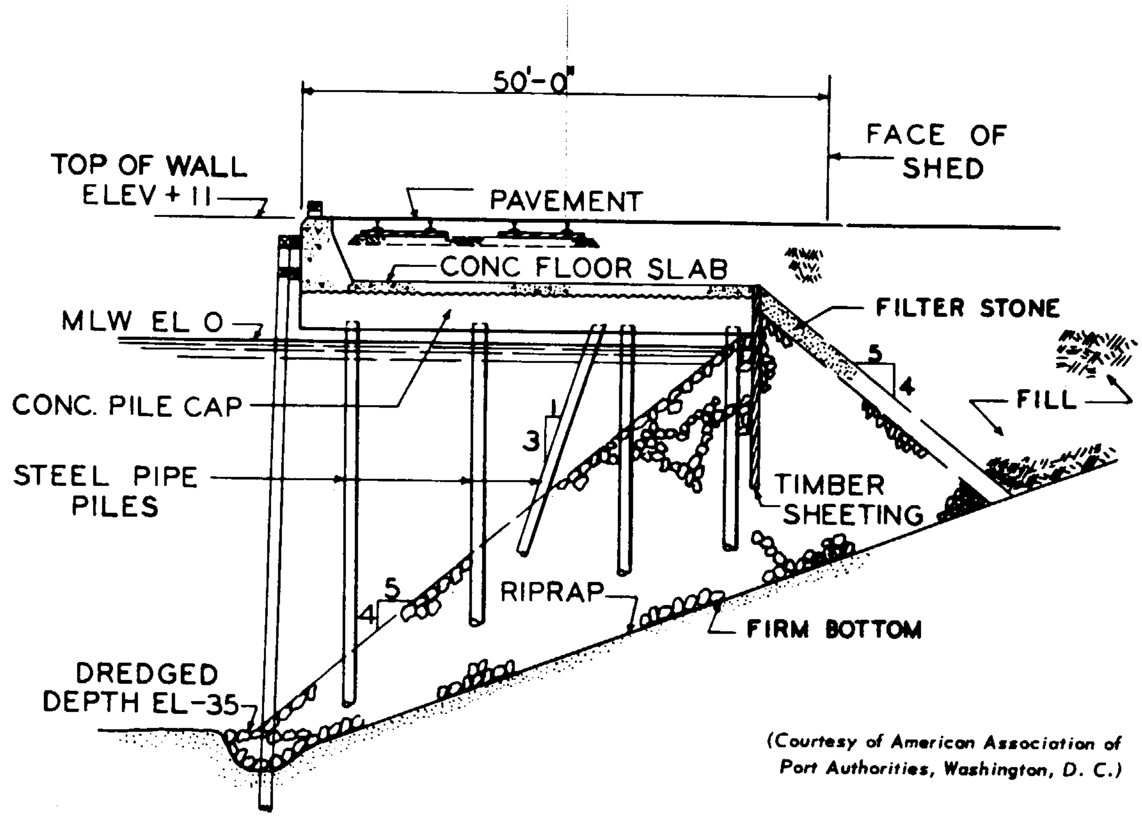


Figure 8-2. Open-Type Wharf Construction with Concrete Relieving Platform on Steel Pipe Piles.

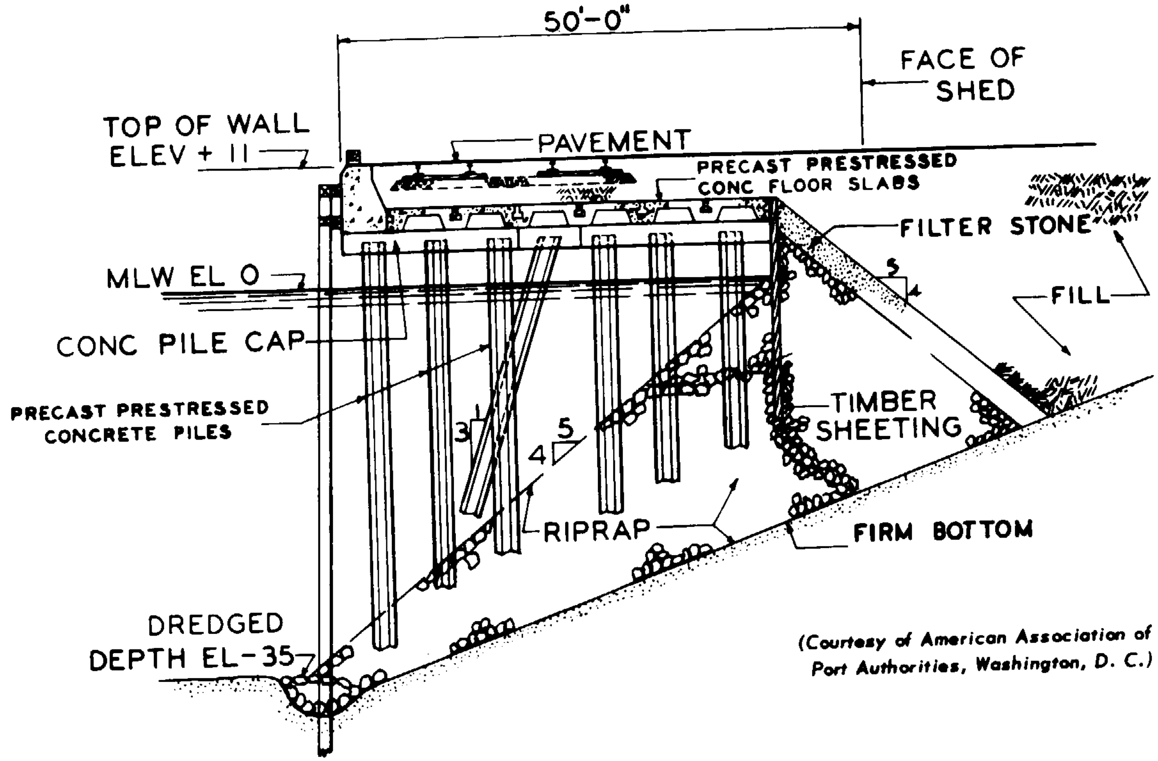


Figure 8-3. Open-Type Wharf Construction with Concrete Relieving Platform on Concrete Pile.

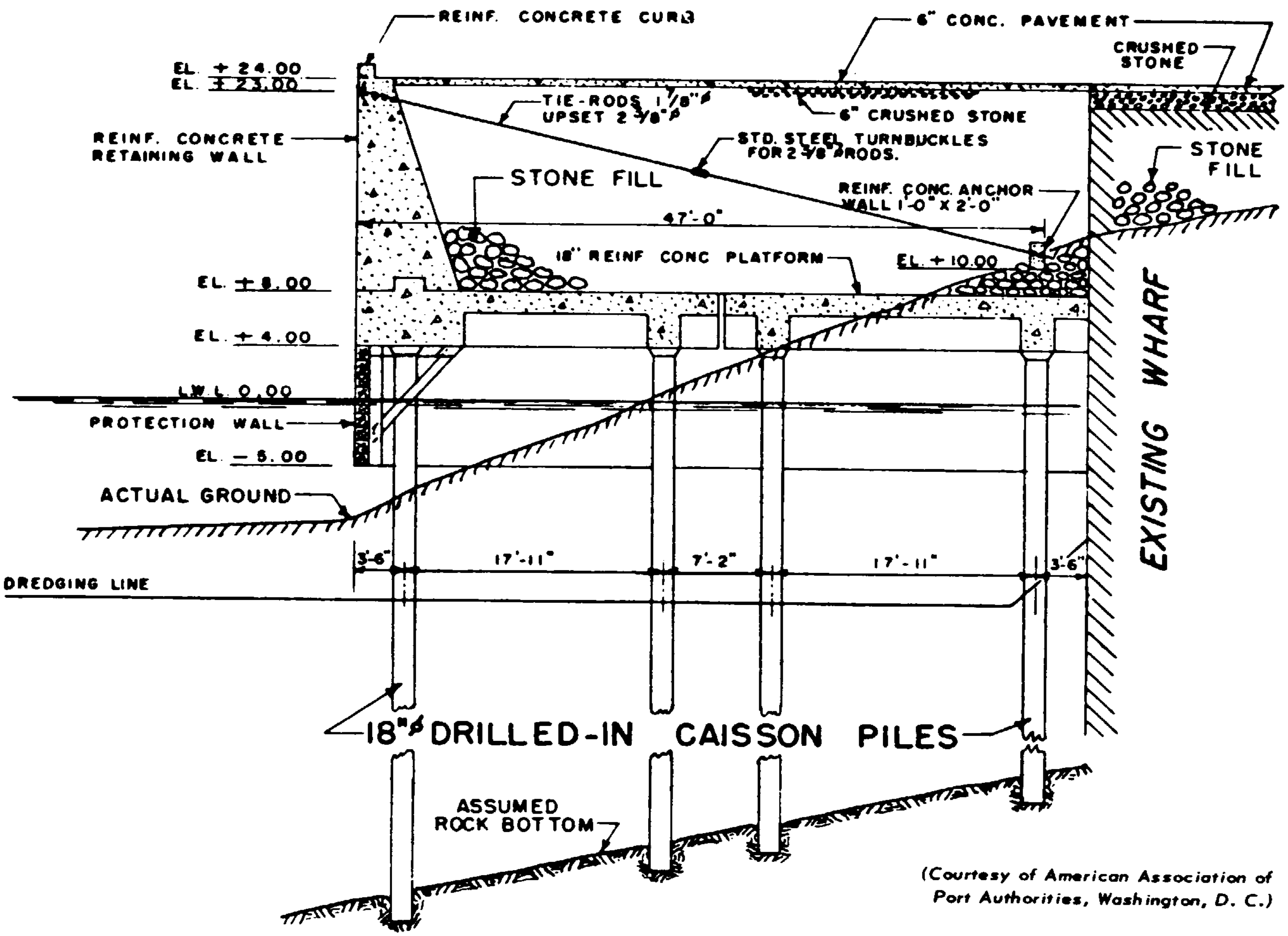


Figure 8-4. Open-Type Wharf Construction with Concrete Relieving Platform on Caisson Piles.

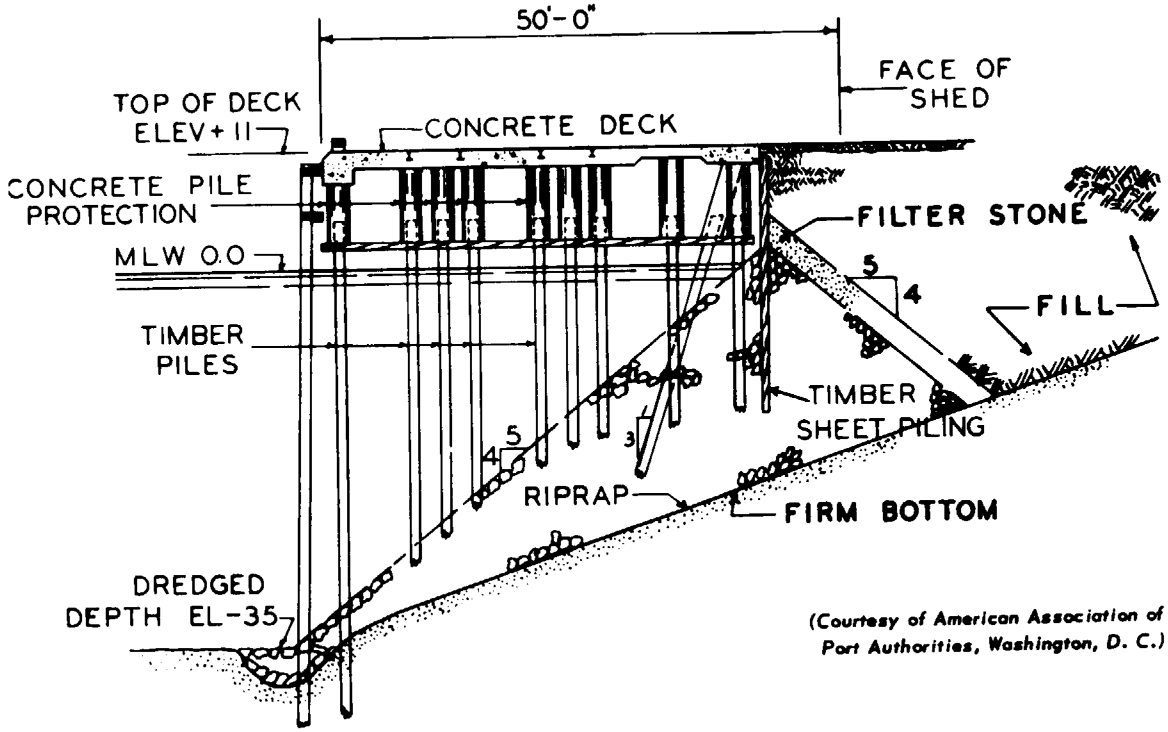


Figure 8-5. High Level Open-Type Wharf Construction with Concrete Deck on Timber Piles.

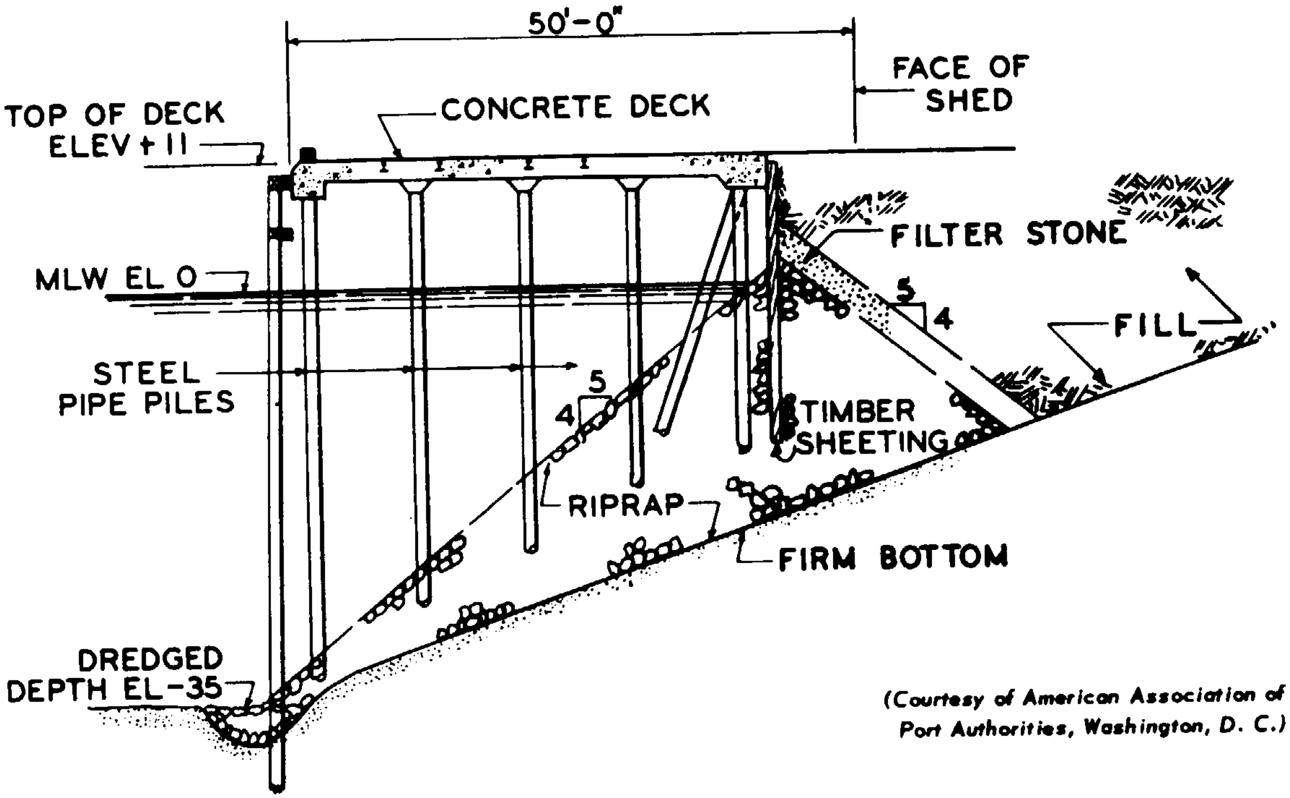


Figure 8-6. High-Level Open-Type Wharf Construction with Concrete Flat Slab Deck on Steel Pipe Piles.

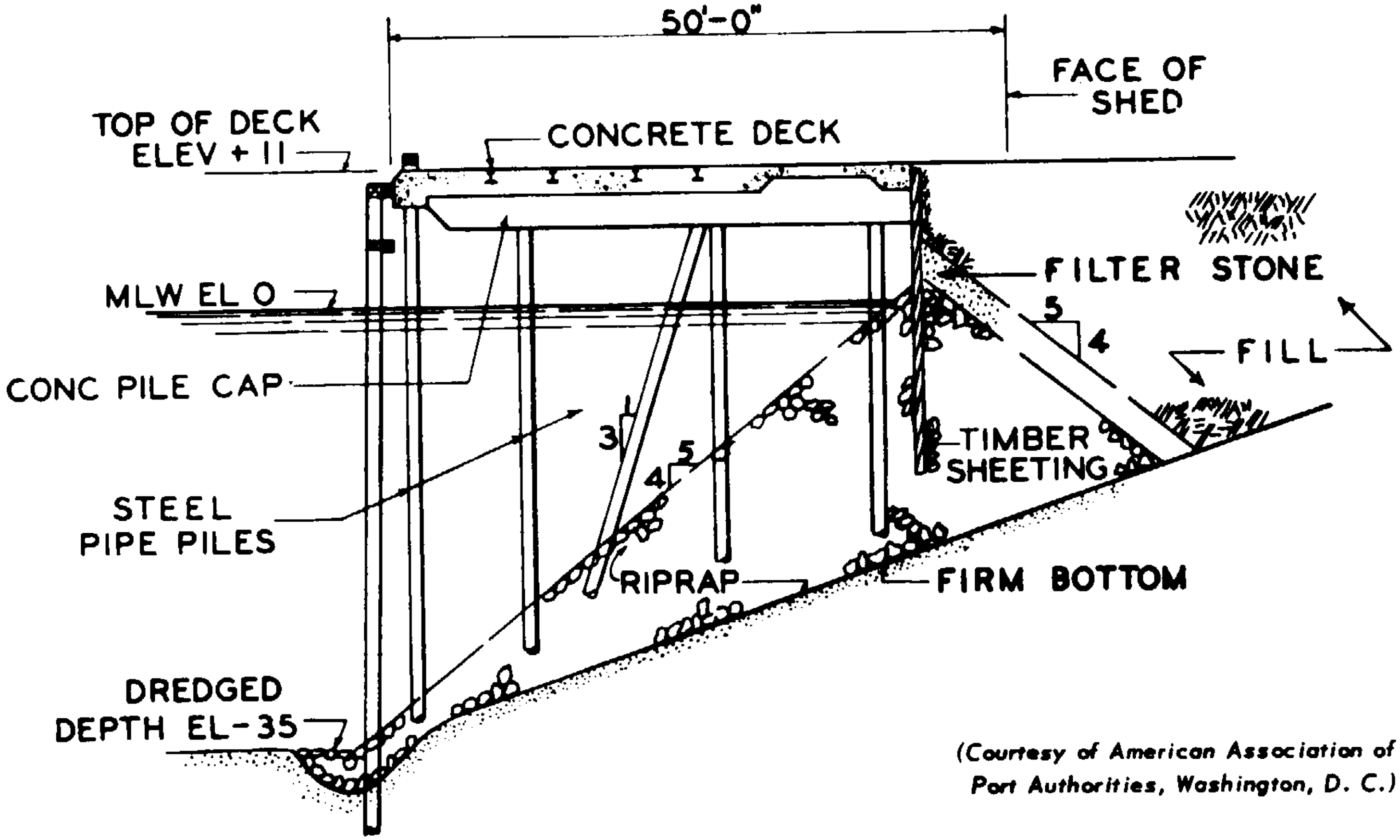


Figure 8-7. High-Level Open-Type Wharf Construction with Concrete Deck on Steel Pipe Piles.

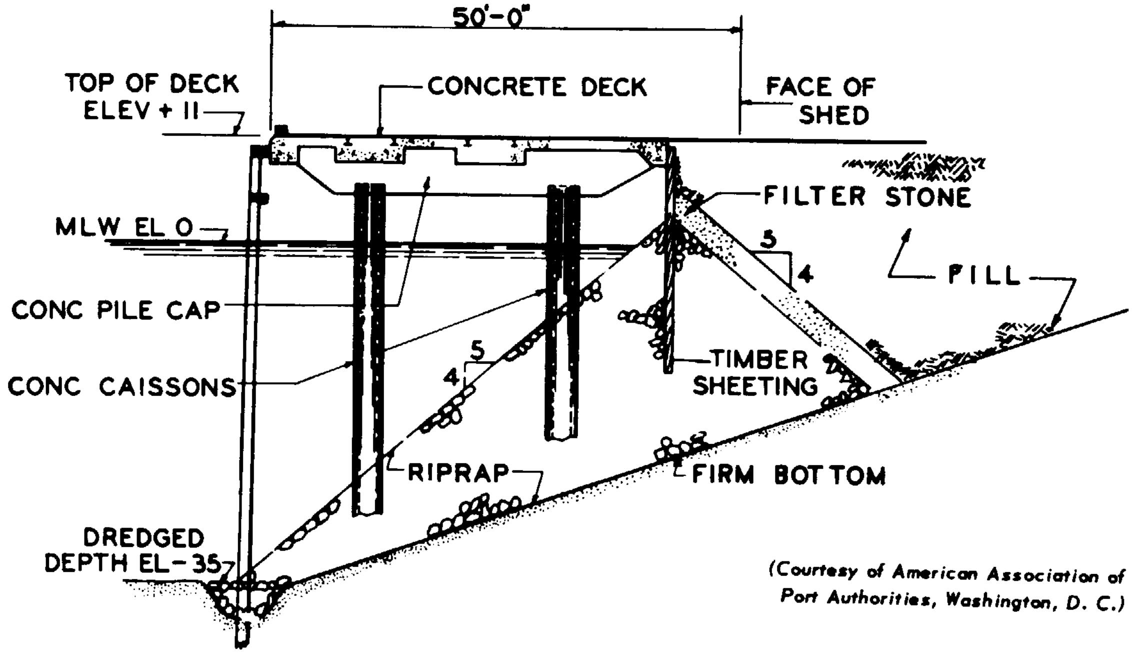


Figure 8-8. High-Level Open-Type Wharf Construction with Concrete Deck on Precast Prestressed Concrete Caissons.

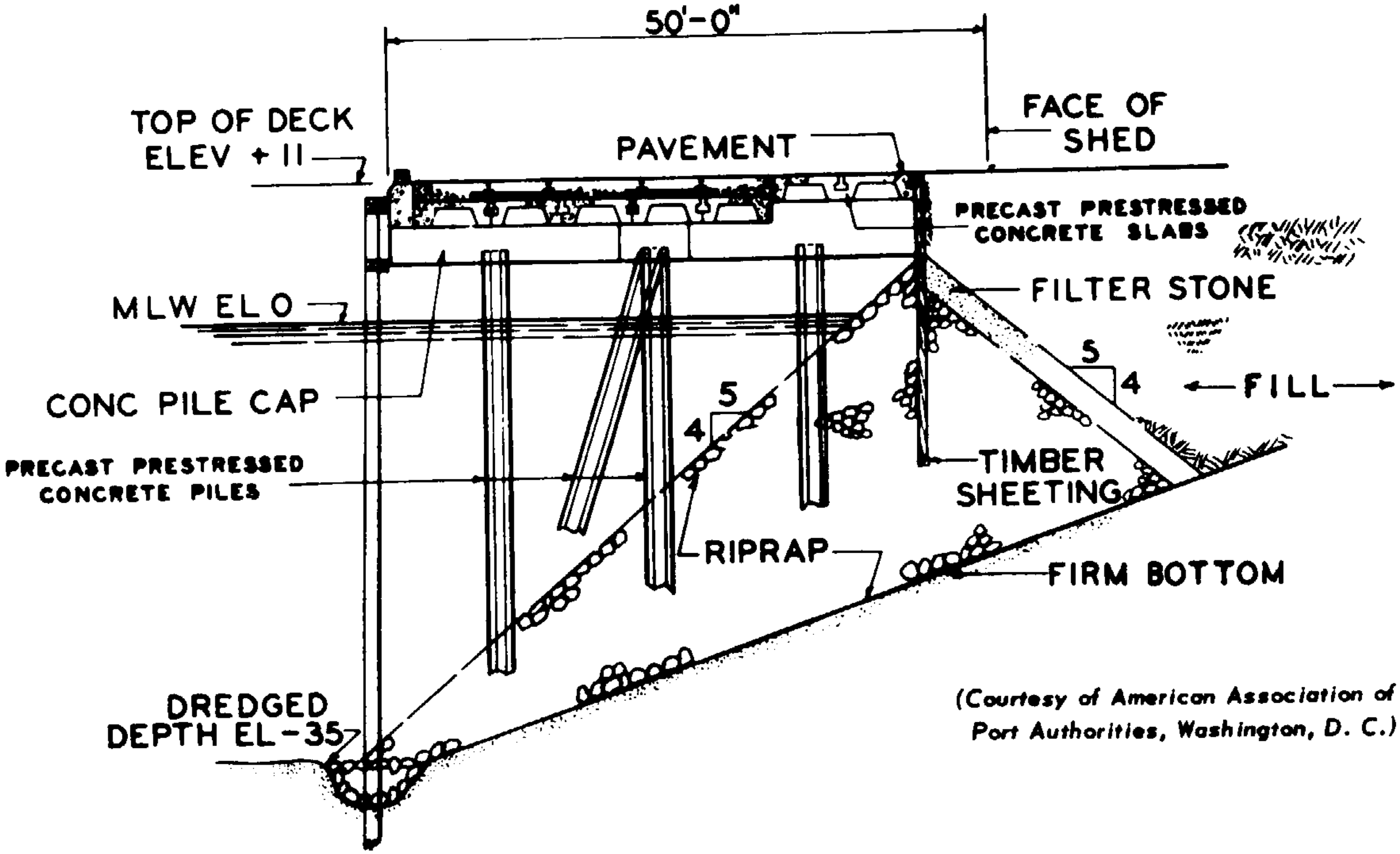


Figure 8-9. High-Level Open-Type Wharf Construction with Precast Concrete Deck on Concrete Piles.

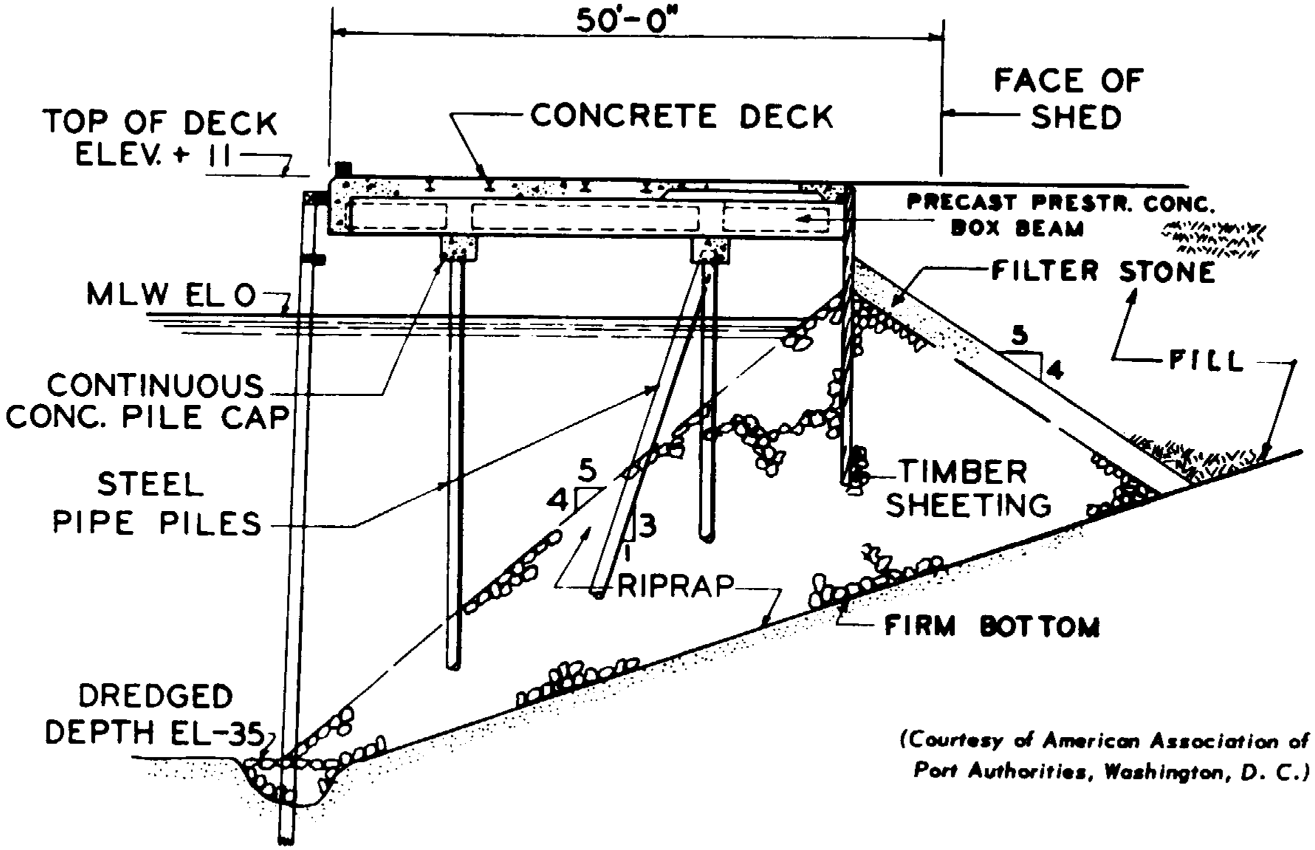


Figure 8-10. High-Level Open-Type Wharf Construction with Concrete Deck on Prestressed Concrete Beams-Steel Pipe Piles.

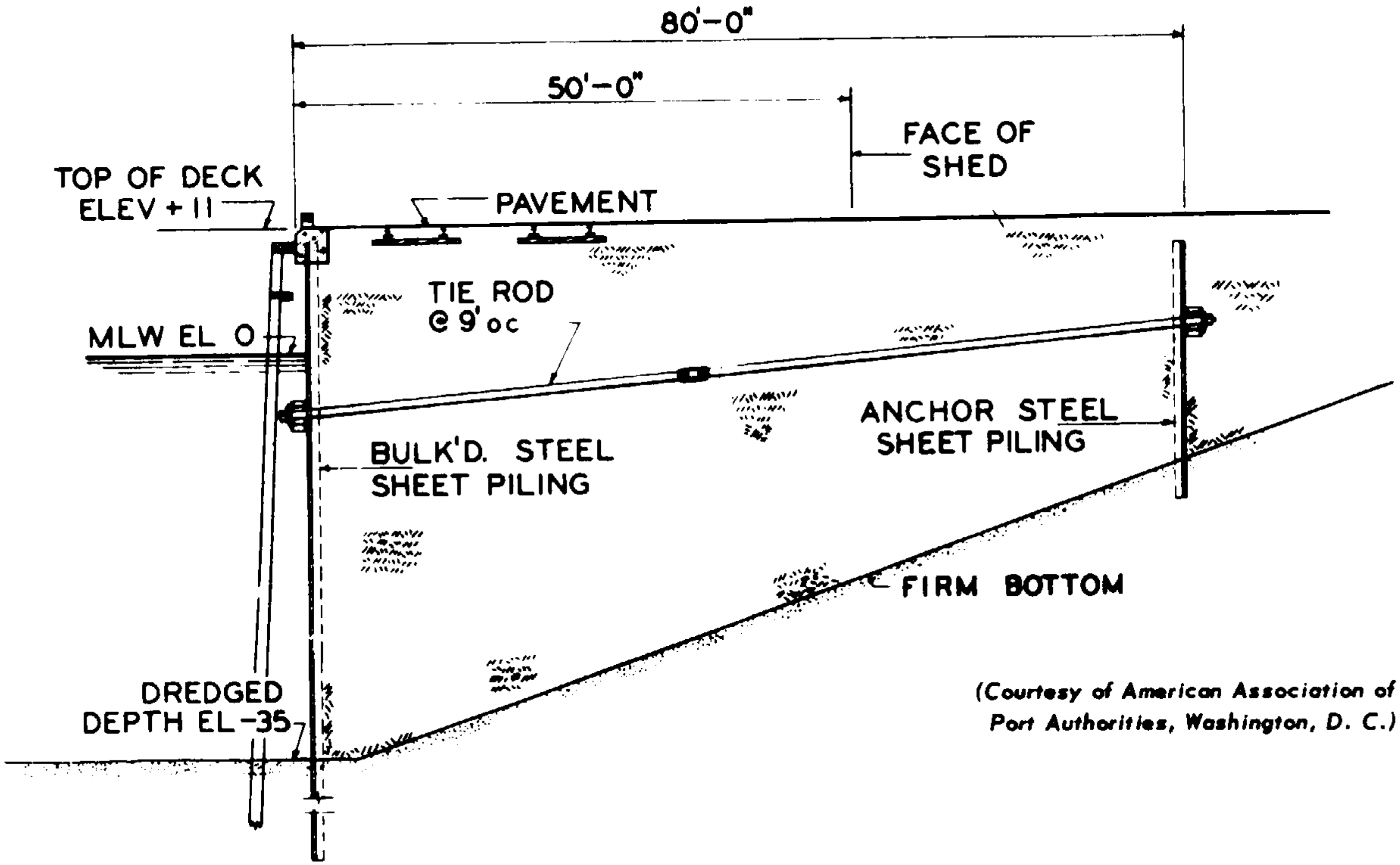


Figure 8-11. Solid fill-type wharf construction with steel sheet pile bulkhead.

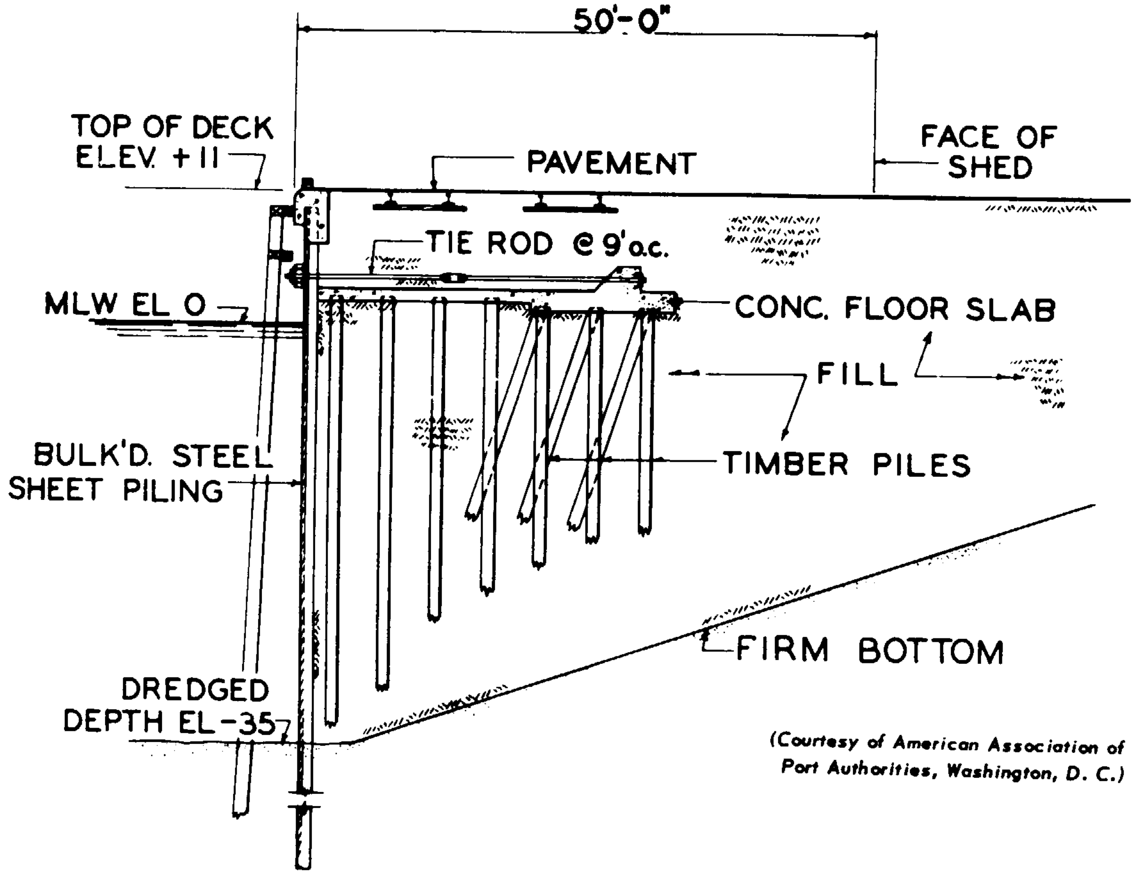


Figure 8-12. Solid fill type wharf construction with steel sheet pile bulkhead and relieving platform anchor.

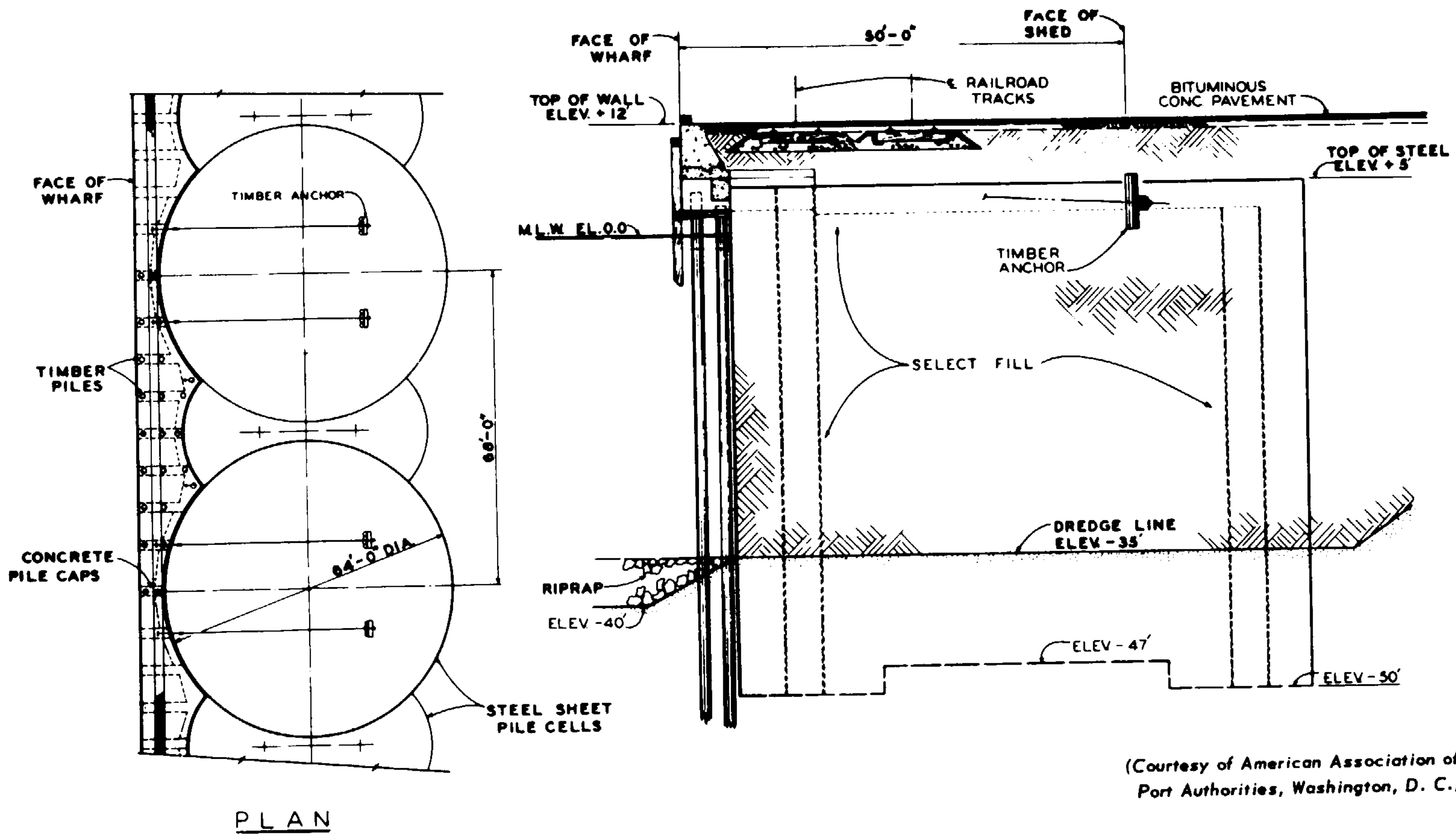


Figure 8-13. Solid fill-type wharf construction with circular steel sheet pile cells.

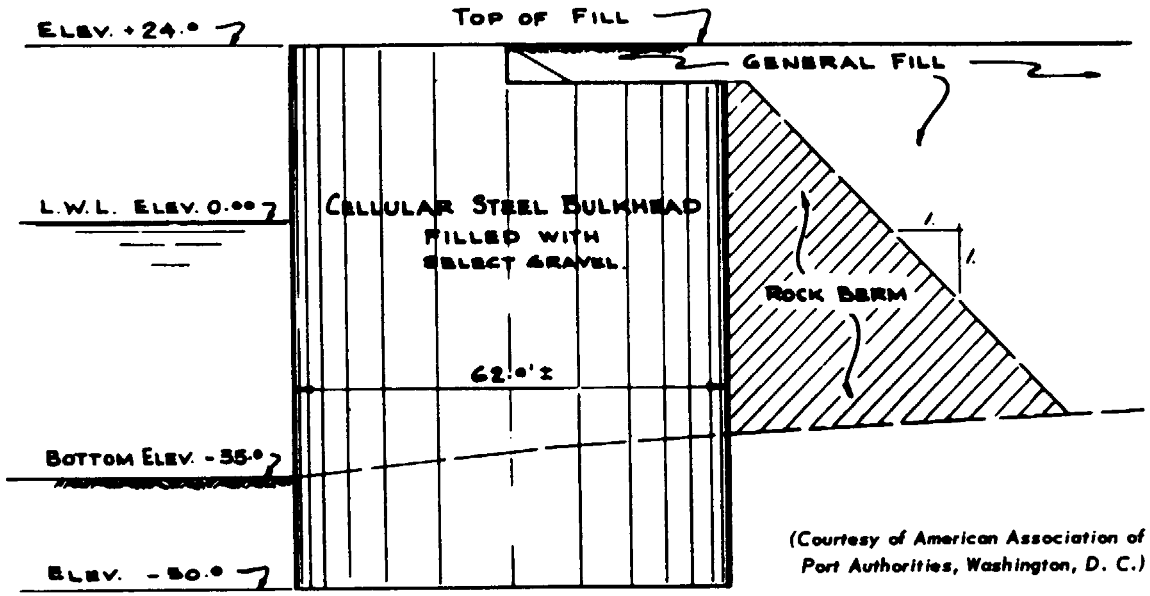


Figure 8-14. Solid fill-type wharf construction with cellular steel bulkhead

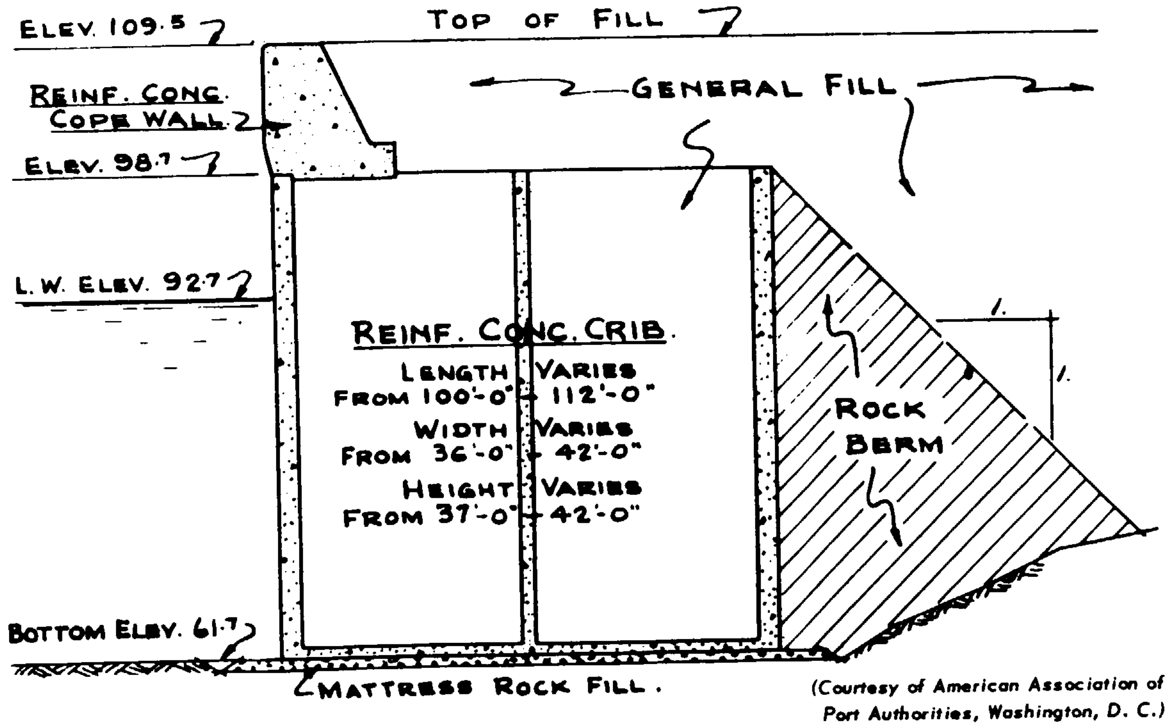


Figure 8-15. Solid fill-type wharf construction with reinforced concrete crib wharf.

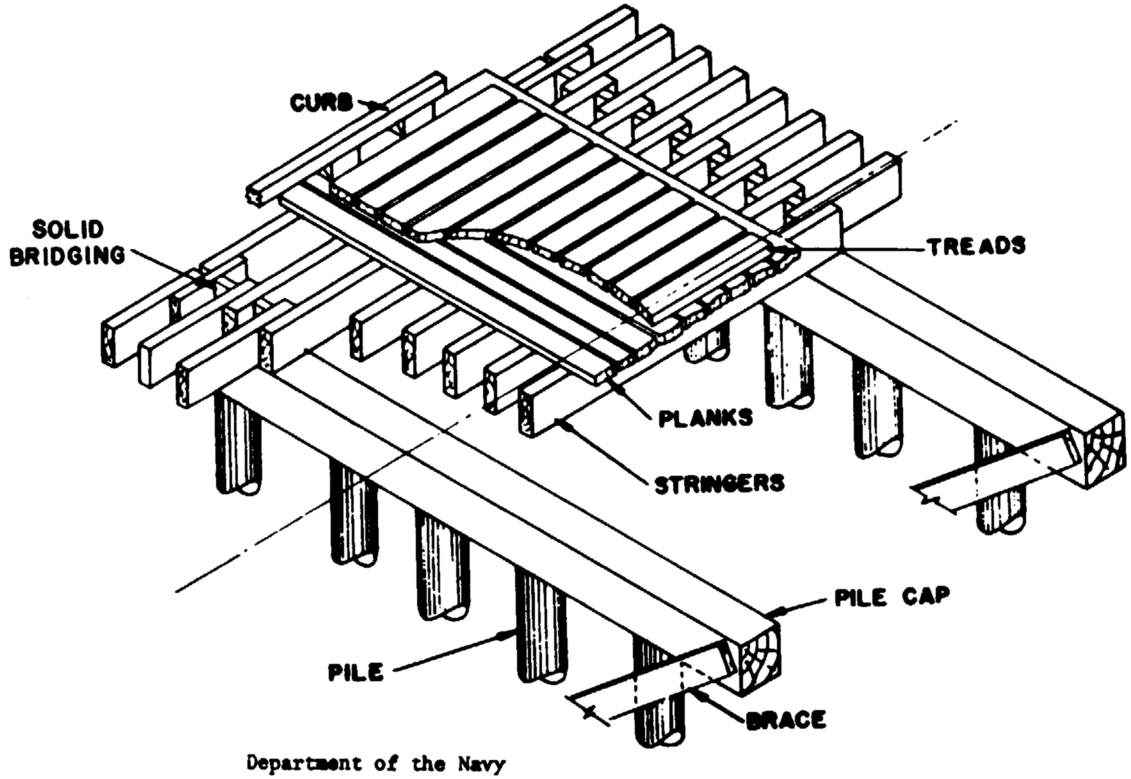
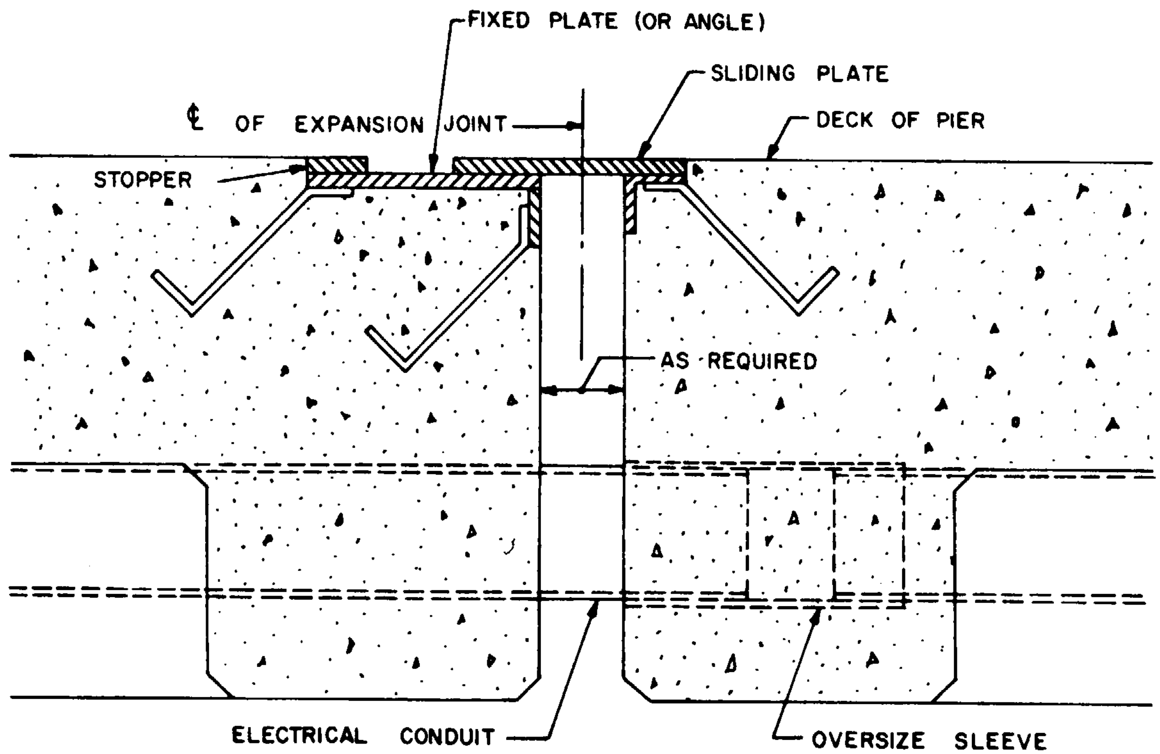


Figure 8-16. Timber deck structure.



Department of the Navy

Figure 8-17. Typical expansion joint detail.